C2. CHAPTER 2
REACTION EFFECTS

C2.1. INTRODUCTION

This chapter describes the expected effects of AE reactions.

C2.2. HD 1.1 EFFECTS

C2.2.1. Blast

C2.2.1.1. Blast Wave Phenomena. In an incident involving HD 1.1 or HD 1.1 with any other HD (a HD 1.1 event), the violent release of energy creates a sudden and intense pressure disturbance termed the "blast wave." The blast wave is characterized by an almost instantaneous rise from ambient pressure to a peak incident pressure (P_i). This pressure increase, or "shock front," travels radially outward from the detonation point, with a diminishing velocity that is always in excess of the speed of sound in that medium. Gas molecules making up the front move at lower velocities. This velocity, which is called the "particle velocity," is associated with the "dynamic pressure," or the pressure formed by the winds produced by the shock front.

C2.2.1.1.1. As the shock front expands into increasingly larger volumes of the medium, the incident pressure decreases and, generally, the duration of the pressure-pulse increases.

C2.2.1.1.2. If the shock wave impinges a rigid surface (e.g., a building) at an angle to the direction of the wave's propagation, a reflected pressure is instantly developed on the surface and this pressure rises to a value that exceeds the incident pressure. This reflected pressure is a function of the incident wave's pressure and the angle formed between the rigid surface and the plane of the shock front.

C2.2.1.2. Partially Confined Explosions. When an explosion occurs within a structure, the peak pressure associated with the initial shock front will be both high and amplified by reflections within the structure. In addition, the accumulation of gases from the explosion will exert additional pressure and increase the load duration within the structure. This effect may damage or destroy the structure unless the structure is designed to either withstand or vent the gas and shock pressures. Structures that have one or more strengthened walls may be vented for relief of excessive gas by either using frangible construction for the remaining walls or roof or through the use of openings. This type of construction will allow the gas from an internal explosion to spill out of the structure. Once released from confinement, these pressures, referred to as "exterior" or "leakage" pressures, expand radially and may affect external structures or personnel.

C2.2.1.3. Quantity-Distance (QD) – K-factors. Throughout this Standard, NEW is used to calculate Quantity-Distance (QD) by means of a formula of the type D (ft) = $K \cdot W^{1/3}$, where

"D" is the distance in feet, "K" is a factor (also called K-factor) that is dependent upon the risk assumed or permitted, and "W" is the NEW in pounds. When metric units are used, the symbol "Q" denotes Net Explosive Quantity (NEQ) in kilograms. In the formula D (m) = $K_m \bullet Q^{1/3}$, the distance "D" is expressed in meters. Thus, the units of the K-factor ("K" in the English system) are ft/lb$^{1/3}$ and ("K_m" in the metric system) m/kg$^{1/3}$. The value of "K" in English units is approximately 2.52 times "K_m." For example, if D (m) = $6 \bullet Q^{1/3}$, then D (ft) = $15.12 \bullet W^{1/3}$. Distance requirements determined by the formula with English units are sometimes expressed by the value of "K," using the terminology K9, K11, K18, to mean K = 9, K = 11, and K = 18.

C2.2.1.4. Expected Blast Pressures at QD. Table C2.T1. presents the incident pressures that would be expected at various K-factors from HD 1.1 events.

Table C2.T1. Expected Peak Incident Pressures from HD 1.1 Events

LOCATION	K-FACTOR (ft/lb$^{1/3}$) *Km-FACTOR [m/kg$^{1/3}$]*	INCIDENT PRESSURE (psi) *[kPa]*
Barricaded Aboveground Intermagazine Distance (IMD)	6 *2.38*	27 *186.2*
Barricaded Intraline Distance (ILD)	9 *3.57*	12 *82.7*
Unbarricaded Aboveground IMD	11 *4.36*	8 *55.2*
Unbarricaded ILD	18 *7.14*	3.5 *24.1*
Public Traffic Route (PTR) Distance		
W< 100,000 lbs	24	2.3
Q< 45,400 kg	*9.52*	*15.9*
W> 250,000 lbs	30	1.7
Q> 113,400 kg	*11.9*	*11.7*
Inhabited Building Distance (IBD)		
W< 100,000 lbs	40	1.2
Q< 45,400 kg	*15.87*	*8.3*
W> 250,000 lbs	50	0.9
Q> 113,400 kg	*19.84*	*6.2*

C2.2.1.5. General Blast Effects On Structures

C2.2.1.5.1. Conventional Structures. Conventional structures are generally designed to withstand roof-snow loads of 0-50 pounds per square foot [0-2.4 kPa] or wind loads up to 90 miles per hour [145 kilometers per hour] or both. At 90 mph [145 kph], the wind load equates to

0.14 psi [1.0 kPa]. Given the pressures shown in Table C2.T1. for the selected K-factors, it is evident that, even at IBD, conventional structures may not provide complete protection from the blast. Generally, the weakest portions of any conventional structure are the windows. Table C2.T2. provides the probability of breaking typical windows at various K-factors and associated incident pressures from HD 1.1 events.

Table C2.T2. Probability of Window Breakage from Incident Pressure

K-FACTOR (ft/lb$^{1/3}$) ***Km-FACTOR*** *[m/kg$^{1/3}$]*	**Incident Pressure** (psi) *[kPa]*	**Probability of Breakage (%) for Windows facing PES**		
		Window 1	**Window 2**	**Window 3**
40 *15.87*	1.2 *8.3*	85	100	100
50 *19.84*	0.9 *6.2*	60	100	100
60 *23.80*	0.7 *4.8*	41	100	100
70 *27.77*	0.6 *4.1*	26	100	100
80 *31.74*	0.5 *3.4*	16	94	100
90 *35.70*	0.4 *2.8*	10	76	100
100 *39.67*	0.3 *2.1*	6	55	100
150 *59.51*	0.2 *1.4*	1	8	49
328 *130.12*	0.0655 *0.45*	0	0.1	0.8

Window 1: 12" x 24" x 0.088" Float annealed (area = 2 ft^2)

30.5 cm x 61 cm x 0.0.223 cm Float annealed (area = 0.186 m^2)

Window 2: 24" x 24" x 0.088" Float annealed (area = 4 ft^2)

61 cm x 61 cm x 0.0.223 cm Float annealed (area = 0.372 m^2)

Window 3: 42" x 36" x 0.12" Float annealed (area = 10.5 ft^2)

106.7 cm x 91.4 cm x 0.0.395 cm Float annealed (area = 0.975 m^2)

C2.2.1.5.2. Above Ground Structures (AGS). These are generally considered conventional structures and provide little protection from blast or fragmentation. (See paragraph C2.2.5.).

C2.2.1.5.3. Earth-Covered Magazines (ECM). High reflected pressure and impulse produced by an explosion at an adjacent ECM can damage doors and headwalls and propel debris into an ECM so that explosion is communicated by impact of such debris upon the contents. When separated from each other by the minimum distances required by Table C9.T6., ECM (see paragraph C5.2.1.) provide virtually complete protection of AE against the propagation effects of an explosion. However, AE in adjacent ECM may be damaged and structural damage ranging from cracks in concrete, damage to ventilators and doors, to complete structural failure, may occur. (When ECM containing HD 1.1 AE are sited so that any one is in the forward sector of another, the two must be separated by distances greater than the minimum permitted for side-to-side orientations. The greater distances are required primarily for the protection of door and headwall structures against blast from a PES forward of the exposed magazine, and to a lesser extent due to the directionality of effects from the source.)

C2.2.1.5.4. Underground Storage Facilities. Underground facilities sited per section C9.7. provide a high degree of protection against propagation of an explosion between chambers, and between underground and aboveground structures. An HD 1.1 explosion in an underground storage facility causes very high pressures of prolonged duration. Blast waves and the accompanying gas flows will travel throughout the underground facility at high velocity.

C2.2.1.5.5. Barricaded Open-Storage Modules. Barricaded open-storage modules (see paragraph C5.2.2.) provide a high degree of protection against propagation of explosion. However, if flammable materials are present in nearby cells, subsequent propagation of explosion by fire is possible. When an explosion occurs, AE in adjacent modules separated by K1.1 [K_m 0.44] will be thrown tens of meters, covered with earth, and unavailable for use until extensive uncovering operations, and possibly maintenance, are completed. Items at K2.52 [K_m 1.0] separation distance from a donor explosion are expected to be readily accessible.

C2.2.1.5.6. High Performance Magazine (HPM). When separated from other AE storage magazines by the minimum distances required by Table C9.T6., the HPM provides virtually complete protection of AE against the propagation effects of an explosion. The HPM's 2-story transfer and storage areas are enclosed by a pre-engineered metal building, which may be severely damaged as a result of an explosion at a nearby PES. The amount of damage to be expected at various pressure levels is described in paragraph C2.2.5. Access to the AE in a HPM may require extensive cleanup and the use of a mobile crane, unless special design considerations are incorporated into the metal building design. The HPM contains multiple storage cells, which are designed to limit the maximum credible event, as discussed in subparagraph C9.3.1.1.3. In the event of an internal explosion involving the maximum credible event (MCE), the pre-engineered metal building can be expected to be completely destroyed, and AE not involved in the explosion can be expected to be significantly damaged and no longer usable.

C2.2.1.6. General Blast Effects on Personnel. Tables C2.T3. through C2.T5. describe the expected effects of blast on personnel.

C2.2.1.7. Computation of Blast Effects. Many of the blast effects described in this section were computed with the DDESB Blast Effects Computer (DDESB Technical Paper (TP) No. 17 (Reference (c))), which can be used to estimate similar effects associated with various NEW, facilities, and distances.

Table C2.T3. General Blast Effects on Personnel – Eardrum Rupture

EFFECT	Incident Pressure (psi) *[kPa]*	K-FACTOR (ft/lb$^{1/3}$) *Km-FACTOR [m/kg $^{1/3}$]*	PROBABILITY (%)
Eardrum Rupture	3.0 *20.7*	20.0 *7.87*	1
	3.6 *24.5*	17.9 *7.08*	2
	4.9 *33.8*	14.6 *5.78*	5
	6.6 *45.7*	12.2 *4.84*	10
	9.0 *62.1*	10.3 *4.10*	20
	15.0 *103.6*	8.0 *3.16*	50
	74.4 *513.0*	3.9 *1.55*	99

Table C2.T4. General Blast Effects on Personnel – Lung Damage

EFFECT	Incident Pressure (psi) *[kPa]*	Pulse Duration (ms)
Lung Damage	174 *1200*	0.5
	94 *648*	1
	31 *214*	5
	22 *152*	10
	15 *103.4*	50
	15 *103.4*	100

Table C2.T5. General Blast Effects on Personnel – Lethality Due to Lung Rupture

EFFECT*	**Weight (lbs)** *[kg]*	**Range (ft)** *[m]*	**K-FACTOR ($ft/lb^{1/3}$)** ***Km-FACTOR*** *[$m/kg^{1/3}$]*	**Incident Pressure (psi)** *[kPa]*	**Pulse Duration (ms)**	**Positive Impulse (psi-ms)** *[kPa-s]*
Lethality due to Lung Rupture	8,000	35.8	1.79	386.9	8.8	412.5
	3,628.7	*10.92*	*0.71*	*2667.8*		*2,844.5*
	27,000	99.8	3.33	107.1	51.1	665.6
	12,247	*30.42*	*1.32*	*738.3*		*4,589.2*
	125,000	189.8	3.80	79.3	82.6	985.3
	56,699	*57.85*	*1.51*	*546.6*		*6,793.8*

* Lethality due to lung rupture is caused by a combination of pressure and impulse. This combination will vary with the charge weight. (NOTE: In this example, the probability of lethality is assumed to be 99.9%.)

C2.2.2. Fragments

C2.2.2.1. General. An important consideration in the analysis of the hazards associated with an explosion is the effect of any fragments produced. Although most common in HD 1.1 or HD 1.2 events, fragmentation may occur in any incident involving AE. Depending on their origin, fragments are referred to as "primary" or "secondary" fragments.

C2.2.2.1.1. Primary fragments result from the shattering of a container (e.g., shell casings, kettles, hoppers, and other containers used in the manufacture of explosives ~~and~~; rocket engine housings) in direct contact with the explosive. These fragments usually are small, initially travel at thousands of feet per second, and may be lethal at long distances from an explosion.

C2.2.2.1.2. Secondary fragments are debris from structures and other items in close proximity to the explosion. These fragments, which are somewhat larger in size than primary fragments and initially travel at hundreds of feet per second, do not normally travel as far as primary fragments.

C2.2.2.1.3. The earth cover of an underground facility may rupture and create a significant debris hazard.

C2.2.2.1.4. A hazardous fragment is one having an impact energy of 58 ft-lb [79 joules] or greater.

C2.2.2.1.5. The Hazardous Fragment Distance is the distance at which the areal density of hazardous fragments or debris becomes one per 600 ft^2 [55.7 m^2].

C2.2.3. Thermal Hazards

C2.2.3.1. General. Generally, thermal hazards from a HD 1.1 event are of less concern than blast and fragment hazards.

C2.2.3.2. Personnel. It normally takes longer to incur injury from thermal effects than from either blast or fragmentation effects because both blast and fragmentation occur almost instantaneously. The time available to react to a thermal event increases survivability.

C2.2.3.3. Structures, Material, and AE. The primary thermal effect on structures, material, and AE is their partial or total destruction by fire. The primary concern with a fire involving AE is that it may transition to a more severe reaction, such as a detonation.

C2.2.4. Groundshock and Cratering

C2.2.4.1. General

C2.2.4.1.1. In an airburst, there may be a downward propagation of groundshock and cratering may be reduced or eliminated.

C2.2.4.1.2. In a surface burst, groundshock is generated and cratering can be significant.

C2.2.4.1.3. A buried or partially buried detonation produces the strongest groundshock; however, if the explosion is deep enough, no crater will be formed.

C2.2.4.2. Underground Facilities. AE protection can be achieved by proper chamber spacing. An HD 1.1 explosion will produce ground shocks that may rupture the earth cover and eject debris. (See section C9.7.)

C2.2.5. Expected Consequences

C2.2.5.1. Barricaded Aboveground Magazine (AGM) Distance - $6W^{1/3}$ ft [$2.38Q^{1/3}$ m] - 27 psi [186.1 kPa]. At this distance:

C2.2.5.1.1. Unstrengthened buildings will be destroyed.

C2.2.5.1.2. Personnel will be killed by blast, by being struck by debris, or by impact against hard surfaces.

C2.2.5.1.3. Transport vehicles will be overturned and crushed by the blast.

C2.2.5.1.4. Explosives-loaded vessels will be damaged severely, with propagation of explosion likely.

C2.2.5.1.5. Aircraft will be destroyed by blast, thermal, and debris effects.

C2.2.5.1.6. Control. Barricades are effective in preventing immediate propagation of explosion by high-velocity, low-angle fragments. However, they provide only limited protection against any delayed propagation of explosives caused by a fire resulting from high-angle firebrands.

C2.2.5.2. Barricaded Intraline Distance (ILD) - 9W$^{1/3}$ ft [3.57Q$^{1/3}$ m] - 12 psi [82.7 kPa]. At this distance:

C2.2.5.2.1. Unstrengthened buildings will suffer severe structural damage approaching total destruction.

C2.2.5.2.2. Personnel will be subject to severe injuries or death from direct blast, building collapse, or translation.

C2.2.5.2.3. Aircraft will be damaged beyond economical repair both by blast and fragments. If the aircraft are loaded with explosives, delayed explosions are likely to result from subsequent fires.

C2.2.5.2.4. Transport vehicles will be damaged heavily, probably to the extent of total loss.

C2.2.5.2.5. Improperly designed barricades or structures may increase the hazard from flying debris, or may collapse in such a manner as to increase the risk to personnel and equipment.

C2.2.5.2.6. Control. Barricading is required. Direct propagation of explosion between two explosive locations is unlikely when barricades are placed between them to intercept high-velocity, low-angle fragments. Exposed structures containing high-value, mission-critical equipment or personnel may require hardening.

C2.2.5.3. Unbarricaded AGM Distance - 11W$^{1/3}$ ft [4.36Q$^{1/3}$ m] - 8 psi [55.3 kPa]. At this distance:

C2.2.5.3.1. Unstrengthened buildings will suffer damage approaching total destruction.

C2.2.5.3.2. Personnel are likely to be injured seriously due to blast, fragments, debris, and translation.

C2.2.5.3.3. There is a 15 percent risk of eardrum rupture.

C2.2.5.3.4. Explosives-loaded vessels are likely to be damaged extensively and delayed propagation of explosion may occur.

C2.2.5.3.5. Aircraft will be damaged heavily by blast and fragments; destruction by resulting fire is likely.

C2.2.5.3.6. Transport vehicles will sustain severe body damage, minor engine damage, and total glass breakage.

C2.2.5.3.7. Control. Barricading will significantly reduce the risk of propagation of explosion and injury of personnel by high-velocity, low-angle fragments.

C2.2.5.4. Unbarricaded ILD - $18W^{1/3}$ ft [$7.14Q^{1/3}$ m] - 3.5 psi [24 kPa]. At this distance:

C2.2.5.4.1. Direct propagation of explosion is not expected.

C2.2.5.4.2. Delayed propagation of an explosion may occur at the ES, as either a direct result of a fire or as a result of equipment failure.

C2.2.5.4.3. Damage to unstrengthened buildings may approximate 50 percent, or more, of the total replacement cost.

C2.2.5.4.4. There is a two percent chance of eardrum damage to personnel.

C2.2.5.4.5. Personnel may suffer serious injuries from fragments, debris, firebrands, or other objects.

C2.2.5.4.6. Fragments could damage the decks and superstructure of cargo ships and overpressure could buckle their doors and bulkheads on weather decks.

C2.2.5.4.7. Aircraft can be expected to suffer considerable structural damage from blast. Fragments and debris are likely to cause severe damage to aircraft at distances calculated from the formula $18W^{1/3}$ [$7.2Q^{1/3}$] when small quantities of explosives are involved.

C2.2.5.4.8. Transport vehicles will incur extensive, but not severe, body and glass damage consisting mainly of dishing of body panels and cracks in shatter-resistant window glass.

C2.2.5.4.9. Control. Suitably designed suppressive construction at PES or protective construction at ES may be practical for some situations. Such construction is encouraged when there is insufficient distance to provide the required protection.

C2.2.5.5. Public Traffic Route Distance (PTRD) (under 100,000 lbs of High Explosives (HE)) $24W^{1/3}$ ft [$9.52Q^{1/3}$ m] - 2.3 psi [15.8 kPa]. At this distance:

C2.2.5.5.1. Unstrengthened buildings can be expected to sustain damage approximately 20 percent of the replacement cost.

C2.2.5.5.2. Occupants of exposed structures may suffer temporary hearing loss or injury from blast effects, building debris and displacement.

C2.2.5.5.3. Although personnel in the open are not expected to be killed or seriously injured by blast effects, fragments and debris may cause some injuries. The extent of these injuries depends largely upon the PES structure and the amount and fragmentation characteristics of the AE involved.

C2.2.5.5.4. Vehicles on the road should suffer little damage, unless they are hit by a fragment or the blast causes a momentary loss of control.

C2.2.5.5.5. Aircraft may suffer some damage to the fuselage from blast and possible fragment penetration, but should be operational with minor repair.

C2.2.5.5.6. Cargo-type ships should suffer minor damage to deck structure and exposed electronics from blast and possible fragment penetration, but such damage should be readily repairable.

C2.2.5.5.7. Control. Barricading can reduce the risk of injury or damage due to fragments for limited quantities of AE at a PES. When practical, suitably designed suppressive construction at the PES or protective construction at the ES may also provide some protection.

C2.2.5.6. PTRD (over 250,000 lbs HE) $30W^{1/3}$ ft [$11.9Q^{1/3}$ m] - 1.7 psi [11.7 kPa]. At this distance:

C2.2.5.6.1. Unstrengthened buildings can be expected to sustain damage that may approximate 10 percent of their replacement cost.

C2.2.5.6.2. Occupants of exposed, unstrengthened structures may be injured by secondary blast effects, such as falling building debris.

C2.2.5.6.3. Pilots of aircraft that are landing or taking off may lose control and crash.

C2.2.5.6.4. Parked military and commercial aircraft will likely sustain minor damage due to blast, but should remain airworthy.

C2.2.5.6.5. Although personnel in the open are not expected to be killed or seriously injured by blast effects, fragments and debris may cause some injuries. The extent of these injuries will largely depend upon the PES structure, the NEW, and the fragmentation characteristics of the AE involved.

C2.2.5.6.6. Control. Barricading or the application of minimum fragmentation distance requirements may reduce the risk of injury or damage due to fragments for limited quantities of AE at a PES.

C2.2.5.7. Inhabited Building Distance (IBD) $40W^{1/3}$ ft - $50W^{1/3}$ ft [$15.87Q^{1/3}$ - $19.8Q^{1/3}$ m] - 1.2 psi - 0.90 psi [8.3 kPa - 6.2 kPa]. At this distance:

C2.2.5.7.1. Unstrengthened buildings can be expected to sustain damage that approximates five percent of their replacement cost.

C2.2.5.7.2. Personnel in buildings are provided a high degree of protection from death or serious injury; however, glass breakage and building debris may still cause some injuries.

C2.2.5.7.3. Personnel in the open are not expected to be injured seriously by blast effects. Fragments and debris may cause some injuries. The extent of injuries will depend upon the PES structure and the NEW and fragmentation characteristics of the AE involved.

C2.2.5.7.4. Control. Elimination of glass surfaces is the best control. If determined to be necessary, reducing the use of glass or the size of any glass surfaces and the use of blast-resistant glass will provide some relief. For new construction, building design characteristics**,** ~~should~~*to* include consideration of how any required glass surfaces are oriented and use of blast-resistant glass*,* ~~to~~*can* reduce glass breakage and structural damage.

C2.3. HD 1.2 EFFECTS

C2.3.1. Blast

C2.3.1.1. HD 1.2, when not stored with HD 1.1 or HD 1.5, is not expected to mass detonate. In an incident involving HD 1.2, when stored by itself or with HD 1.3, HD 1.4, or HD 1.6 (a HD 1.2 event), AE can be expected to both explode sporadically and burn. Fire will propagate through the mass of the AE over time. Some AE may neither explode nor burn. Blast effects from the incident are limited to the immediate vicinity and are not considered to be a significant hazard.

C2.3.1.2. An HD 1.2 event may occur over a prolonged period of time. Generally, the first reactions are relatively nonviolent and, typically, begin a few minutes after flames engulf the AE. Later reactions tend to be more violent. Reactions can continue for some time (hours), even after a fire is effectively out. Generally, smaller AE tends to react earlier in an incident than larger AE.

C2.3.1.3. The results of an accidental explosion in an underground facility will depend on the type and quantity of munitions, the type of explosion produced, and the layout of the facility. Hazards created outside the underground facility will likely not be as severe as those produced by HD 1.1 or 1.3 material.

C2.3.2. Fragments

C2.3.2.1. The primary hazard from a HD 1.2 event is fragmentation. Fragmentation may include primary fragments from AE casings or secondary fragments from containers and structures. At longer ranges, primary fragments are the major contributors to fragment hazards.

C2.3.2.2. During a HD 1.2 event, fragmentation may extensively damage exposed facilities. However, less fragmentation damage can be expected from a given quantity of HD 1.2 than would be expected from the corresponding quantity of HD 1.1 because not all the HD 1.2 will react.

C2.3.3. Thermal Hazards

C2.3.3.1. An incident involving a quantity of HD 1.2 poses considerably less thermal risk to personnel than an incident involving corresponding quantities of either HD 1.1 or HD 1.3 because a HD 1.2 event's progressive nature allows personnel to immediately evacuate the area.

C2.3.3.2. A HD 1.2 event's progressive nature provides an opportunity for a fire suppression system, if installed, to put out a fire in its early stages.

C2.3.4. Ejected Items. In HD 1.2 events, a reaction may eject (lob) unreacted-AE or AE components from the event site. These ejected items may subsequently react.

C2.3.5. Propelled Items. In HD 1.2 events, some AE or AE components may become propulsive and travel well beyond IBD.

C2.3.6. Firebrands. In an incident involving only HD 1.2 or HD 1.2 with HD 1.4, firebrands are considered to be a hazard only in the immediate vicinity of the incident site.

C2.3.7. Expected Consequences

C2.3.7.1. The expected consequences for HD 1.2 AE are similar to those for HD 1.1. The effects of HD 1.2 AE are NEW dependent.

C2.3.7.2. The principal hazard to personnel in the open, to aircraft, and to occupied vehicles is fragments.

C2.3.7.3. Airblast, fragment, and thermal hazards to buildings and parked aircraft or vehicles cannot be predicted reliably because the effects will depend on the MCE.

C2.4. HD 1.3 EFECTS

C2.4.1. Gas Pressures. In an incident involving only HD 1.3 or HD 1.3 with HD 1.4 (a HD 1.3 event):

C2.4.1.1. Where sufficient venting is provided, gas pressures generated by the event are not a significant concern. Examples of sites with sufficient venting include open storage and structures where internal pressures do not exceed 1-2 psi [6.9-13.8 kPa] (non-confinement structure).

C2.4.1.2. Where venting is insufficient, internal gas pressures may be substantial. In such situations, these pressures may blow out vent panels or frangible walls and, in some instances, cause partial or complete structural failure.

C2.4.1.3. Where there is minimal venting and structural containment (extreme confinement), a detonation of the HD 1.3 may occur with effects similar to those of a HD 1.1 explosion. For example, HD 1.3 AE is considered as HD 1.1 (mass explosion) for QD purposes when stored in underground chambers.

C2.4.2. Fragments. In an HD 1.3 event, fragments are considerably less hazardous than those produced by HD 1.1 and HD 1.2 events. Internal gas pressures may produce fragments from the bursting of containers or the rupture of containment facilities. In general, such fragments will be large and of low velocity. (For exceptions, see subparagraph C2.4.1.3.)

C2.4.3. Thermal Hazards. In an HD 1.3 event, heat flux presents the greatest hazard to personnel and assets. Energetic materials in HD 1.3 articles include both fuel components and oxidizers. Burning these materials emits fuel-rich flammable gases, fine particles, or both. This unburned material may ignite when it comes in contact with air and cause a large fireball. This fireball will expand radially from the ignition site and could wrap around obstacles, even those designed to provide line-of-sight protection from HD 1.1 events. Shields and walls can be designed to provide protection from thermal effects (see Chapter 4).

C2.4.3.1. The nominal spherical fireball that would be expected from the rapid burning of HD 1.3 can be calculated by $D_{FIRE} = 10 \times W_{EFF}^{1/3}$ where "D_{FIRE}" is the diameter of the fireball (ft) and "W_{EFF}" is the quantity of HD 1.3 involved (lb), multiplied by a 20 percent safety factor (e.g., "W" of 100 pounds = "W_{EFF}" of 120 pounds) [D_{FIRE} (meters) = 3.97 x W_{EFF} (kilograms)$^{1/3}$].

C2.4.3.2. In addition to the fireball itself, the thermal flux from the fireball can ignite fires out to Intermagazine Distance (IMD).

C2.4.4. Propelled Items. In an HD 1.3 event, some AE or AE components may become propulsive and travel well beyond IBD.

C2.4.5. Firebrands. In an HD 1.3 event, a severe fire-spread hazard may result from firebrands projected from the incident site. Firebrands can be expected to be thrown more than 50 ft [15.2 m] from a HD 1.3 event. Firebrands can ignite fires well beyond the distance to which a fireball poses a threat.

C2.4.6. Expected Consequences

C2.4.6.1. Exposed personnel may receive severe burns from fireballs or flash burning in an HD 1.3 event. The hazard distance is dependent on the quantity and burning rate of the HD 1.3 involved.

C2.4.6.2. Buildings, vehicles, and aircraft may be ignited by radiant heat, sparks, or firebrands or may be damaged by heat (searing, buckling, etc.).

C2.4.6.3. Personnel in nearby buildings, vehicles, or aircraft may be injured unless evacuated before heat conditions reach hazardous levels.

C2.5. HD 1.4 EFFECTS

C2.5.1. Blast. There is no blast associated with an incident involving only HD 1.4 (an HD 1.4 event).

C2.5.2. Fragmentation. An HD 1.4 event will not produce fragments of appreciable energy (i.e., greater than 14.8 ft-lbs [20 joules]). Fragments from HD 1.4S have energies less than or equal to 5.9 ft-lbs [8 joules].

C2.5.3. Thermal Hazard. AE given this designation are considered to provide only a moderate fire hazard. A fireball or jet of flame may extend 3 feet [1 m] beyond the location of the HD 1.4 event. A burning time of less than 330 seconds (5.5 minutes) for 220 lbs [100 kg] of the HD 1.4 AE is expected.

C2.5.4. Firebrands. No fiery projections are expected beyond 50 feet [15.2 m].

C2.5.5. Compatibility Group (CG) -S Items. HD 1.4 AE assigned a CG-S designation (see subparagraph C3.2.2.1.13.) is the most benign of all AE. In an HD 1.4 event that only involves CG-S, the expected blast, thermal, and projection effects will not significantly hinder fire fighting or other emergency responses.

C2.5.6. Expected Consequences. There may be minor consequences (projection, fire, smoke, heat, or loud noise) beyond the AE itself.

C2.6. HD 1.5 EFFECTS

HD 1.5 effects are similar to those produced by HD 1.1, without the fragmentation effects.

C2.7. HD 1.6 EFFECTS

HD 1.6 effects are similar to those produced by HD 1.3.